Presence detection solution

using XENSIV™ KIT_CSK_BGT60TR13C 60 GHz radar

About this document

Scope and purpose

This document describes the presence detection solution (PDS) using XENSIV™ KIT_CSK_BGT60TR13C kit, provided as part of the connected sensor kit (CSK) offering from Infineon.

Additionally, the document describes the required software and hardware, as well as how to set up and get started with PDS using XENSIV™ KIT_CSK_BGT60TR13C.

Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems interested in building their own presence detection solution for various consumer applications using the CYSBSYSKIT-DEV-01 kit and XENSIV™ BGT60TR13C radar sensor.

Table of contents

1 Presence detection solution

Presence detection is an application of a radar system, where the radar can identify if there are any targets in a specified vicinity. Specifically, the radar continuously detects targets within an angle coverage up to a certain distance. Infineon's presence detection solution (PDS) described here uses a frequency modulated continuous wave (FMCW) radar.

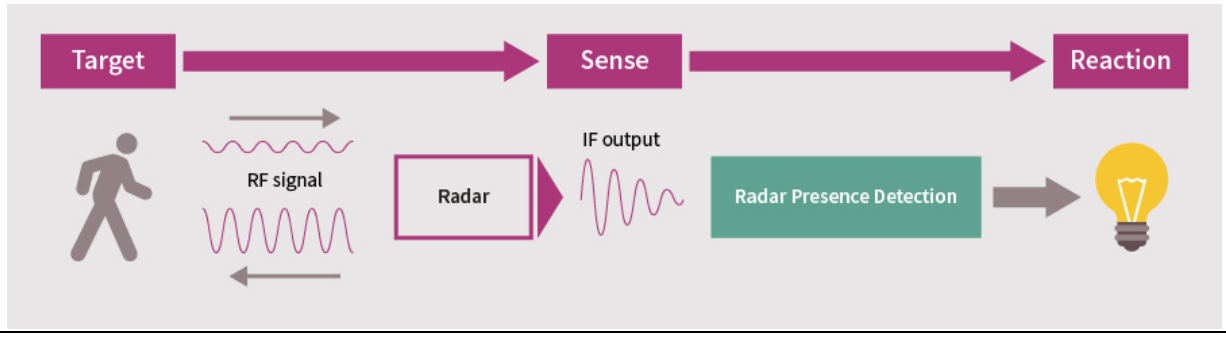


Figure 1 Presence detection using 60 GHz radar sensor

Presence detection can be further utilized for applications such as keyword-less authentication, automatic interaction of smart devices, and the advantage of using a radar system can operate 24x7 unmanned without getting affected by lighting conditions in the room.

Infineon's radar presence detection solution enables the detection of human presence within a configured range. Enabled by Infineon XENSIV™ BGT60TR13C radar (60 GHz radar, antenna-in-package) with its sophisticated radar presence detection algorithms, this solution provides extremely high accuracy in detecting both macro- and micro-movements. Figure 2 shows a high-level representation of presence detection.

Infineon's presence detection algorithm consists of a state machine comprising the following three states:

- Micro presence
- Macro presence
- Absence state

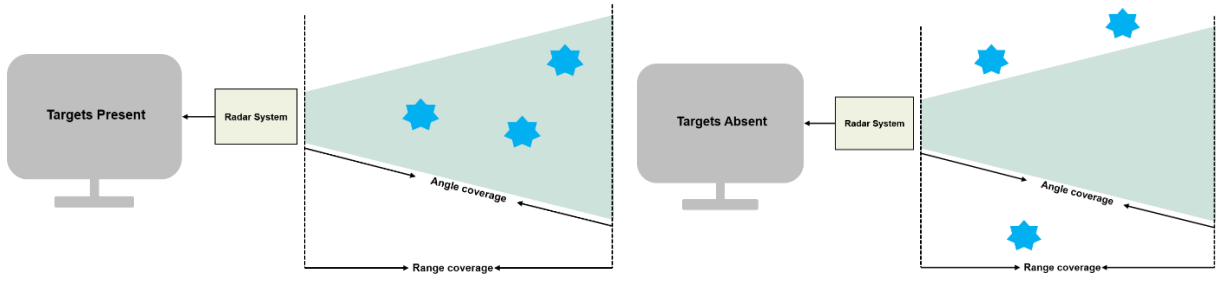


Figure 2 Presence detection principle

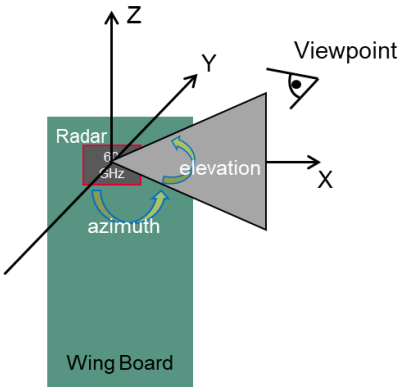
The current presence detection application provides the flexibility to configure the following parameters such as maximum range, micro and macro thresholds, enabling and disabling of bandpass and decimation filters, and to select different setup mode.

1.1 Key features

- Ready-to-use radar solution with adjustable detection range and sensitivity for presence detection.
- Ability to detect micro-movements
- Radar sensor's immunity to environmental factors including temperature, wind, sunlight, and dust/debris.
- Full compliance with the General Data Protection Regulation (GDPR).
- A reliable and tested solution for presence detection, suitable for retail, office, and commercial buildings.

1.2 Solution specifications

Table 1 Solution specifications

Specification	Description
Moving object size	Detect moving objects with a minimum height of 1 m
Field of view (FoV) and radar orientation	• Detection range: Up to 5 m • Azimuth: ± 45 degrees, elevation: ± 40 degrees • Radar chip mounted in front-facing orientation at 1 to 1.5 m height from the ground *Note: Front-facing orientation example – radar wing board mounted on a wall with radar chip on the top side of the board as shown below).* 
Detection range	• Macro-motion (regular human movements): Minimum: 0.66 m, Maximum: ≤ 5 m • Micro-motion: Minimum: 0.66 m, Maximum: ≤ 5 m • Static objects (non-living) are not detected
Macro-motions	• Detection of major movements typically full body movements for instance a person walking into or through the field of view (also referred to as Motion Detection). • A range fast Fourier transform (FFT) is performed on the raw data from the radar after preprocessing to measure the beat frequency, amplitude, and phase frequency of the target. • Typically, this type of motions can be detected with low chirp counts, therefore, making this type of applications suitable for low-power. **Use case:** Motion detection, for awaking the camera only when there in presence (replacement of PIR) to optimize power consumption.

Specification	Description
Micro-motions	• Detection of minute movements such as: – Detection of a stationary human via heartbeat or by rising and falling of chest movements due to breathing (on condition that the human is in the radar's line of sight) – Small finger gestures when typing – Small head movements when reading a book • On top of the range FFT performed on the radar raw data, an incremental doppler FFT is then carried out to determine the frequency, amplitude, and phase frequency of the target. • Micro motion detections require larger chirp counts to determine more data points. Therefore, the power consumption is typically higher than in macro motion applications. **Use case:** Measuring heartbeat, breathing rate, gesture controls.
Detection timings	Can detect presence and absence in real time (≤ 1 s), when at least one moving object is present in the field of view. Declaration of presence/absence states is configurable (time) along with the ability to introduce constant delays (1 to 30 s) before absence state is activated.
Configurability	Easy configuration options using radar presence detection code example using UART port to change various parameters (maximum detection range, sensitivity, selection of filters, modes, etc.)
Target platform	CSK comprising: • Rapid IoT Connect Developer Kit (CYSBSYSKIT-01): Based on PSoC™ 6 MCU (Arm® Cortex®-M4F) • XENSIV™ BGT60TR13C radar wing
CPU and memory consumption	CPU: ~10 percent (target platform), SRAM usage: < 100 KB, FLASH: < 256 KB
HW interface	Presence information is available via UART or GPIO with optional provision for SPI/I2C interface as well using radar presence detection code example.
Certifications	PDS is FCC-certifiable. Recommended radar settings and test report on using an embedded reference form factor board can be provided on request.
Test conditions	Radar chip mounted at height of 1 to 1.5 m from the ground in front-facing orientation (radar sensor on the top side). Test subject height: ~1.7 m Ambient temperature: 18 to 24°C Relative humidity (RH): 35 to 70 percent
Target applications	Homes, offices, and commercial buildings

1.3 Known limitations

Addressing the limitations of the developed application, Table 2 summarizes the constraints with additional information on how they may impact the functionality of the application.

Table 2 Known limitations

Limitation	Description	Considerations
Mounting height	The current verification is conducted for a front-facing wall-mount configuration with the hardware mounted in a vertical orientation, placing the radar sensor on the top side.	The recommended mounting height for the radar board is 1.1 to 1.4 m to ensure optimal coverage of the torso area of most adults.
Detection range reduction at angles	The detection range may decrease at angles based on the sensitivity setting in use. For instance, when employing medium sensitivity at (+45 degrees, -45 degrees), the macro-movement detection range might decrease to 4 to 4.5 m, while the micro-movement detection range might reduce to 3.5 to 4.0 m.	Higher sensitivity settings are beneficial for achieving longer ranges at angles.
Detection issues may arise with fast-moving objects	The maximum supported speed of moving objects is 2 m/s. Detection issues may arise with fast-moving objects or human targets at speeds exceeding this limit.	Consider if you intend to use the solution for fast-moving objects.
Target detection through walls	The solution does not support the elimination of target detection through walls.	Consider an alternative approach for such scenarios.
Glass wall optimization	The solution is not designed or optimized for presence detection through glass walls.	None.
Potential reactivity to moving conditions	The solution might react to certain moving conditions (e.g., moving curtains, plant movements, facing a wall within its active zone, etc.)	Consider either to install it in a location where such conditions can be avoided or adapt the maximum range accordingly.
Generic presence detection	The solution detects presence in the event of motion, regardless of the type of moving objects (e.g., humans, pets, service robots, etc.).	Consider if you intended to use the solution for human detection.

2 Hardware and software requirements

2.1 Hardware requirements

The PDS is implemented and tested on boards is shown in Figure 3. However, the code can be migrated to use other combinations.

- Rapid IoT Connect Developer (CYSBSYSKIT-DEV-01) V3.0
- XENSIV™ BGT60TR13C Wing (EVAL_BGT60TR13C_Wing) V1.0

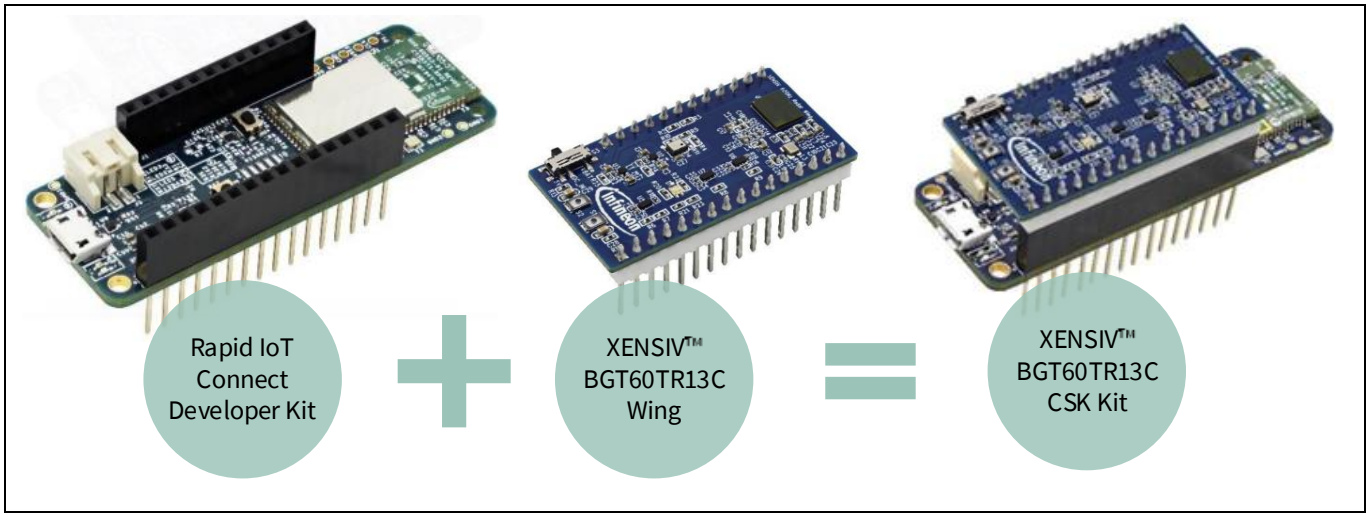


Figure 3 XENSIV™ KIT CSK BGT60TR13C

Note: For more detailed description of the hardware components, see the KIT_CSK_BGT60TR13C user guide [1].

2.1.1 Rapid IoT Connect Developer Kit

Rapid IoT Connect Developer Kit (CYSBSYSKIT-DEV-01) shown in Figure 4 allows for evaluation of the Rapid IoT Connect module (CYSBSYS-RP01) on a standard Feather form factor. CYSBSYS-RP01 Rapid IoT Connect module is a turnkey module that enables secure, scalable, and reliable compute and connect.

Rapid IoT Connect Developer Kit carries a CYSBSYS-RP01 Rapid IoT connect system-on-module (SoM). The Rapid IoT Connect SoM includes, single-chip radio, onboard crystals, oscillators, chip antenna, and passive components.

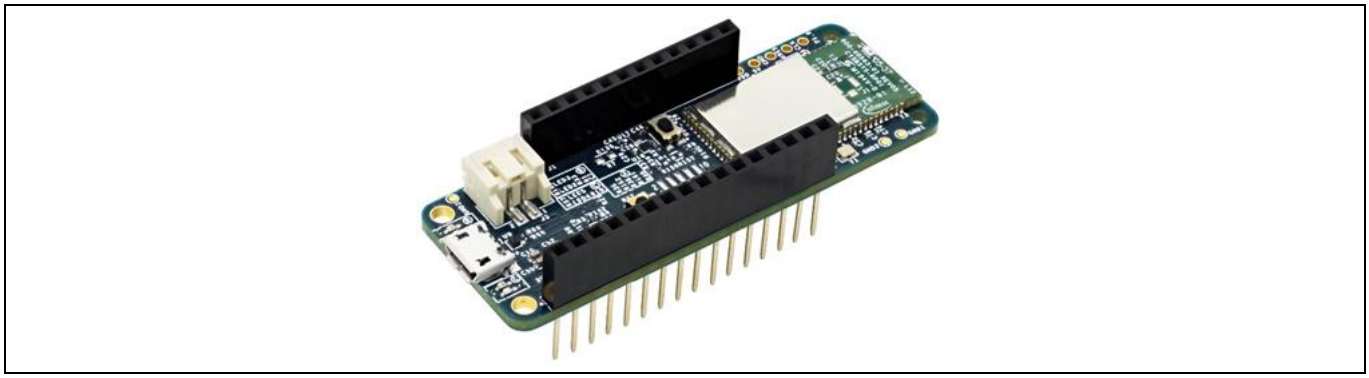


Figure 4 CYSBSYSKIT-DEV-01

Key features:

- CYSBSYS-RP01 module.
- Supports up to 2 MB FLASH and 1 MB SRAM.
- 512 Mbit external Quad SPI NOR FLASH that provides a fast, expandable memory for data and code.
- KitProg3 onboard SWD programmer/debugger, USB-to-UART, and USB-I2C bridge functionality.
- Battery connector, charging IC, and charging indicator LED.
- KitProg3 mode button, KitProg3 status LED, and KitProg3 power LED.
- 16 KB of emulated EEPROM.
- Feather-compatible pin header.
- Delivers dual-cores with a 150 MHz Arm® Cortex®-M4 as the primary application processor and a 100 MHz Arm® Cortex®-M0+ as the secondary processor for low-power operations.
- Supports Full-Speed USB, a Quad-SPI interface, 13 Serial Communication Blocks, 7 programmable analog blocks, and 56 programmable digital blocks.

2.1.2 XENSIV™ BGT60TR13C Wing

XENSIV™ BGT60TR13C Wing shown in Figure 5 is based on the BGT60TR13C MMIC 60 GHz radar sensor with integrated one transmitting and three receiving antennas. BGT60TR13C MMIC enables ultra-wide bandwidth frequency modulated continuous waves (FMCW) operation. It is equipped with an integrated finite-state machine (FSM). With the aid of the FSM, BGT60TR13C can perform FMCW frequency sweeps (so-called chirps), data acquisition as well as storing of samples into the internal FIFO memory autonomously.

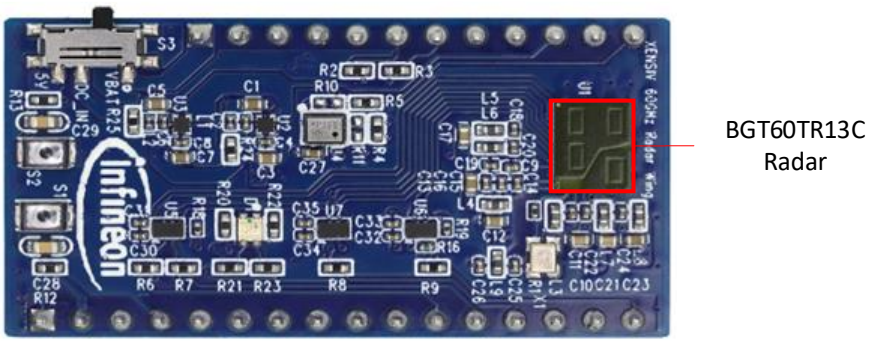


Figure 5 XENSIV™ BGT60TR13C Wing (top view)

BGT60TR13C features:

- It has an ultra-wide bandwidth of 5.5 GHz and a very low range resolution down to ~3 cm.
- Higher Doppler velocity is achieved with a ramp-up speed of 400 MHz/µs.
- High signal-to-noise ratio (SNR) ensures detection of people up to 10 m distance, front facing towards the sensor, while high sensitivity allows detection of movements down to sub-millimeter. Via the very commonly used Serial Peripheral Interface (SPI).
- 60 GHz radar sensor for FMCW operation.
- Antenna-in-package.
- Optimized power modes for low-power operation.

2.2 Software requirements

- ModusToolbox™ software v3.0 or later (tested with v3.0)
- Board support package (BSP) minimum required version: 3.0.0
- Programming language: C
- Serial terminal (Tera Term, ModusToolbox™ IDE terminal, etc.)

3 Mounting guidelines and coverage

To properly mount the hardware unit of the CSK, which includes the radar wing board and rapid IoT baseboard, it is recommended to follow these guidelines:

- Mount it on a wall or tabletop at 1 to 1.5 m height from the ground.
- Mount the unit in such a way that the radar wing board is in front-facing orientation (radar chip on top side).
- Ensure to set the maximum range parameter (e.g., set the value lower than the distance to the opposite wall to avoid reflection).
- With the above conditions met, Figure 6 shows a representative coverage map of radar sensor created in open space based on around 1.7 m test subject at standard room temperature and humidity conditions.

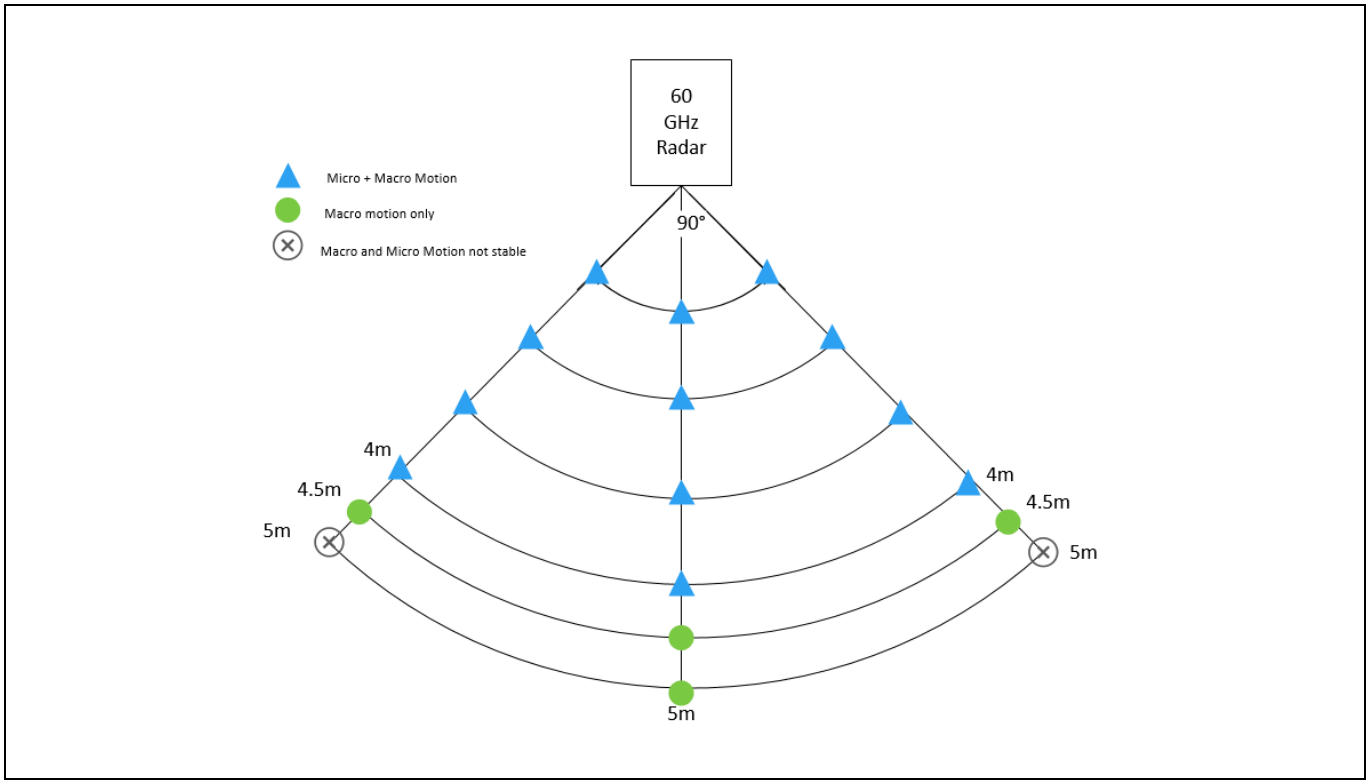


Figure 6 Representative coverage map of radar sensor for certain conditions

4 Quick IoT Experience

4.1 Signup and login

1. Create an account with the Infineon Rapid IoT Connect Platform by signing up with your email address and other required details as shown in the following figure.

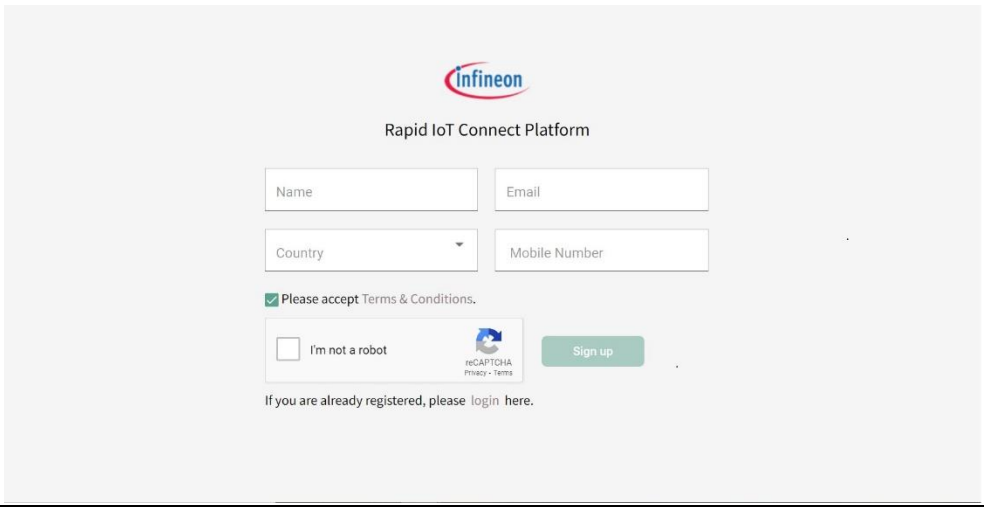


Figure 7 Rapid IoT Connect Platform signup

2. You will receive a password via email, which you will be prompted to change upon your first login to one of your choosing.
3. Enter the credentials to login as shown in the following figure.

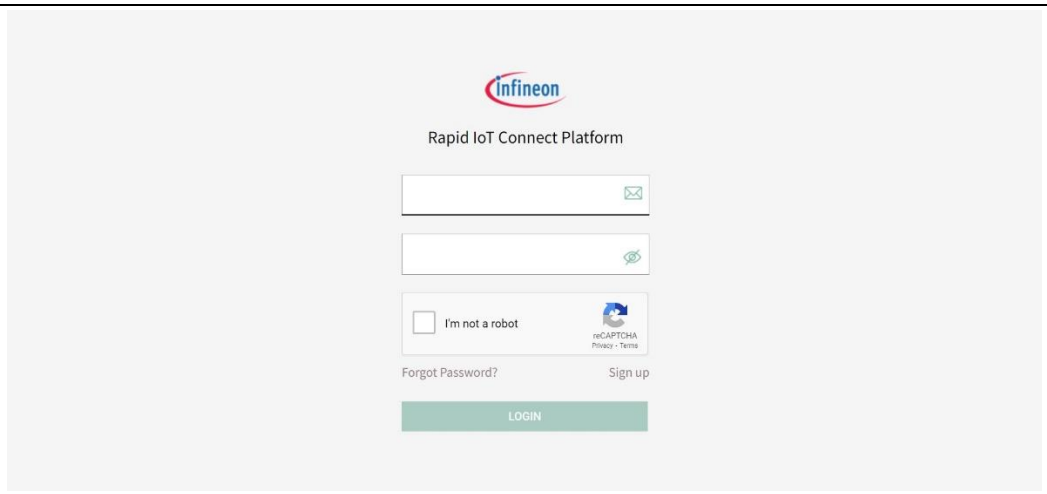


Figure 8 Rapid IoT Connect Cloud Platform login

4.2 Add your device

1. Click on the **Add device** button to start the process of adding your new KIT CSK BGT60TR13C device. A pop-up wizard appears to guide you through the process.

Figure 9 Add your device

2. On the **Device Details**, provide a name for your device, and enter the development kit serial number as shown in the following figure. Click the **Next** button to proceed further.

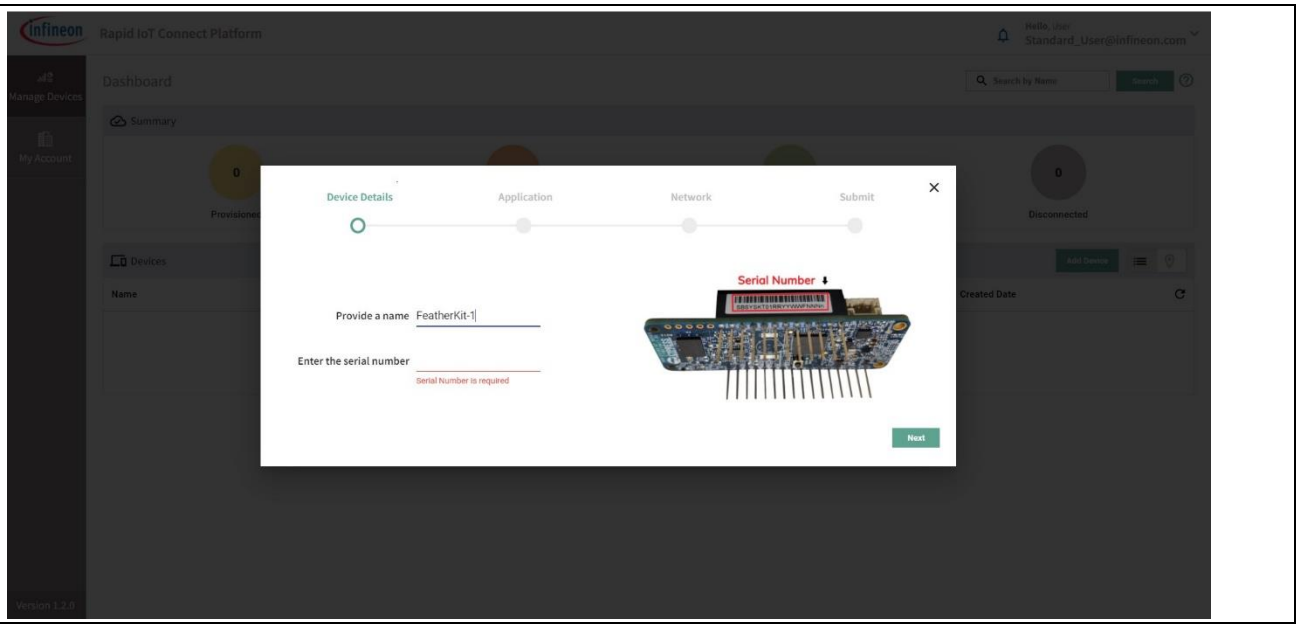


Figure 10 Add device wizard

4.3 Application

- With the Quick IoT Experience in **Application**, you can complete an IoT sensor experience that includes telemetry and fleet monitoring, in less than ten minutes.
- After you complete the setup wizard, download and program your development kit with a pre-built *hex* file. This *hex* file prepares and configures your development kit with the latest Wi-Fi firmware, an example application, and all the credentials required to securely connect to the cloud.
- Note that the example application automatically uses the integrated temperature sensor. Ensure to select your desired application based on the XENSIV™ wing board you have, in this case it is XENSIV™ BGT60TR13C wing.

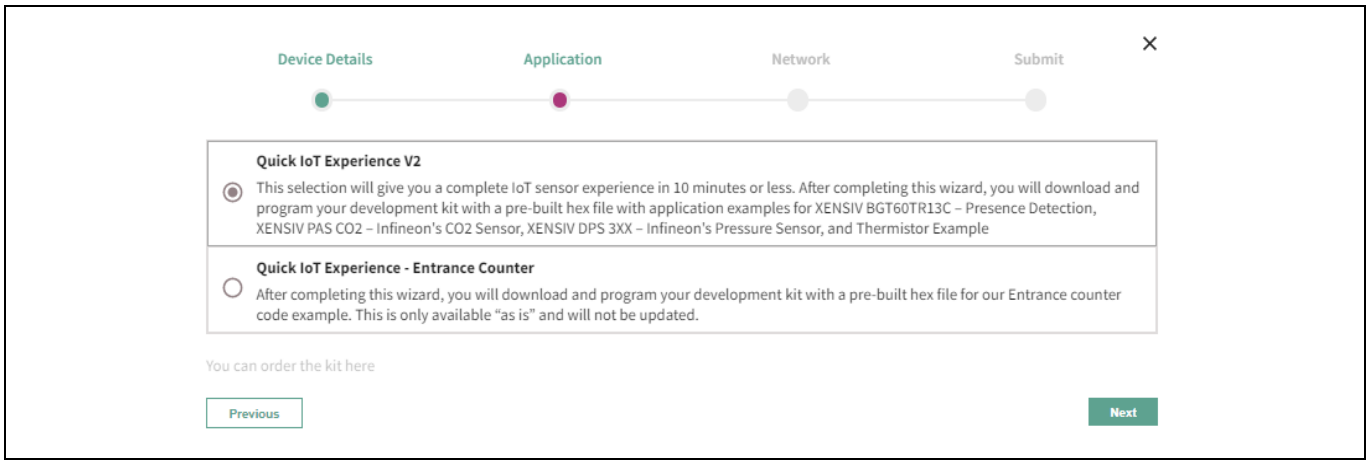


Figure 11 Select application

4.4 Configure Wi-Fi network

You can connect to your preferred WPA2 network by providing the Wi-Fi SSID and password by selecting **Create New Network**, or set up an access point/hotspot with WPA2-PSK security by using the following credentials:

- SSID: IFX_Sensor
- Security: WPA2-PSK
- Password: S66M14022021

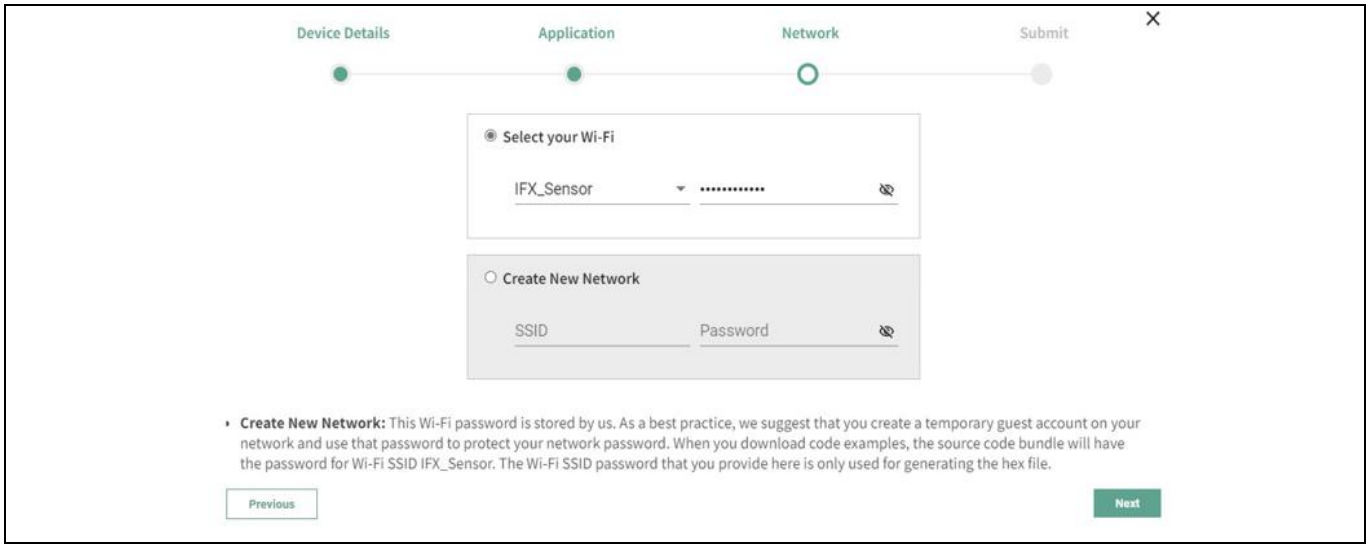


Figure 12 Configure and select network

4.5 Submit your device configurations

- Ensure all the information that you have entered is accurate before clicking the **Submit** button.
- If you need to make changes, you can go back to earlier screens by pressing the **Previous** button.
- After you click **Submit**, a custom *hex* file will be built for your device, and a software bundle will be generated for programming your development kit, as shown in Figure 13.

Note: You can add/register a maximum of five devices with the Rapid IoT Connect Cloud Platform account.

4.6 Download the zip package

Depending on your laptop or PC's operating system (Windows/Linux/Mac), you will receive a downloadable package that includes a *hex* file firmware image and a programming tool for your KIT_CSK_BGT60TR13C kit. The package will be in the form of a zip file. To view the detailed device status, click on the ⊕ (expand) button. To download the zip package, click (download) next to **Success** on the application as shown in Figure 13.

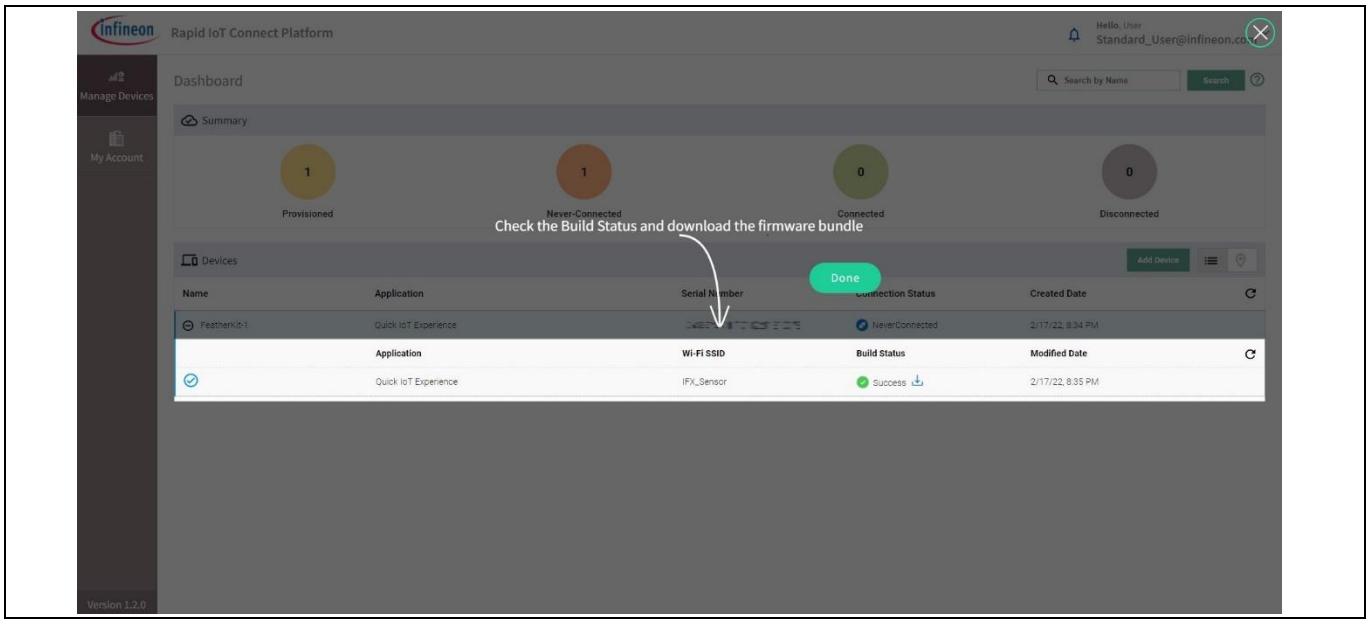


Figure 13 Device management dashboard

4.7 Program the KIT_CSK_BGT60TR13C

- Use a Micro-USB cable to connect your development kit to your PC or laptop.
- Extract the zip file and run the program_kit script.

  For Windows users, the script will be a *.cmd* file, while Linux and Mac users will see a *.sh* and *.command* files, respectively. If you are using Linux or Mac, ensure to run the script from a terminal with the necessary permissions. For detailed instructions, see the README.md file as shown in Figure 14.

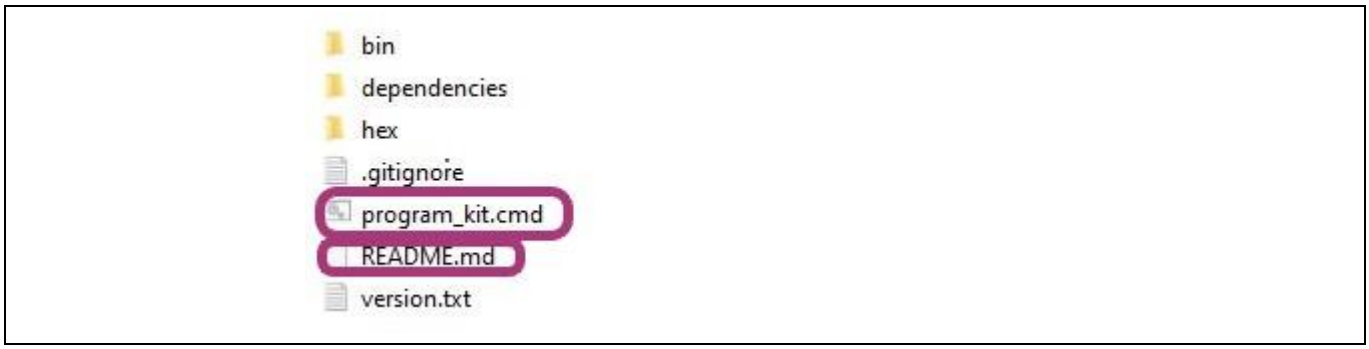


Figure 14 Package content

4.8 Device management

Manage your device or devices and their configurations in the device management tab. To view the details of a particular device, click on the expand icon next to its **Created Date** entry.

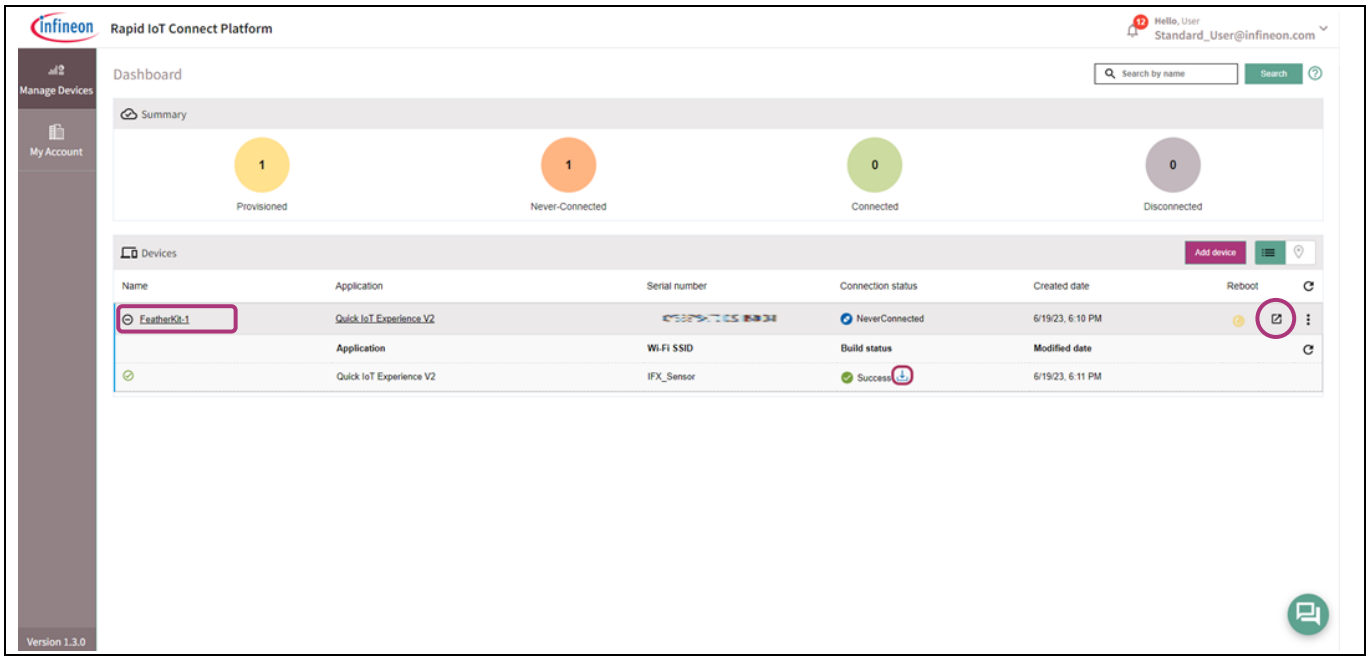


Figure 15 Device connection status

4.9 Select desired application

- To select the desired application for your connected Infineon sensor wing board (in this case, XENSIV™ BGT60TR13C wing), go to the **Attributes** tab in the device details.
- Click on the dropdown menu for Sensor_Solution and select the desired value. By default, the application will be set to **Thermistor** because the only sensing element available on the CYSBSYSKIT-DEV-01 is a thermistor.
- After you select the application, the attributes will be pushed to the device, and it will reboot to the desired application.

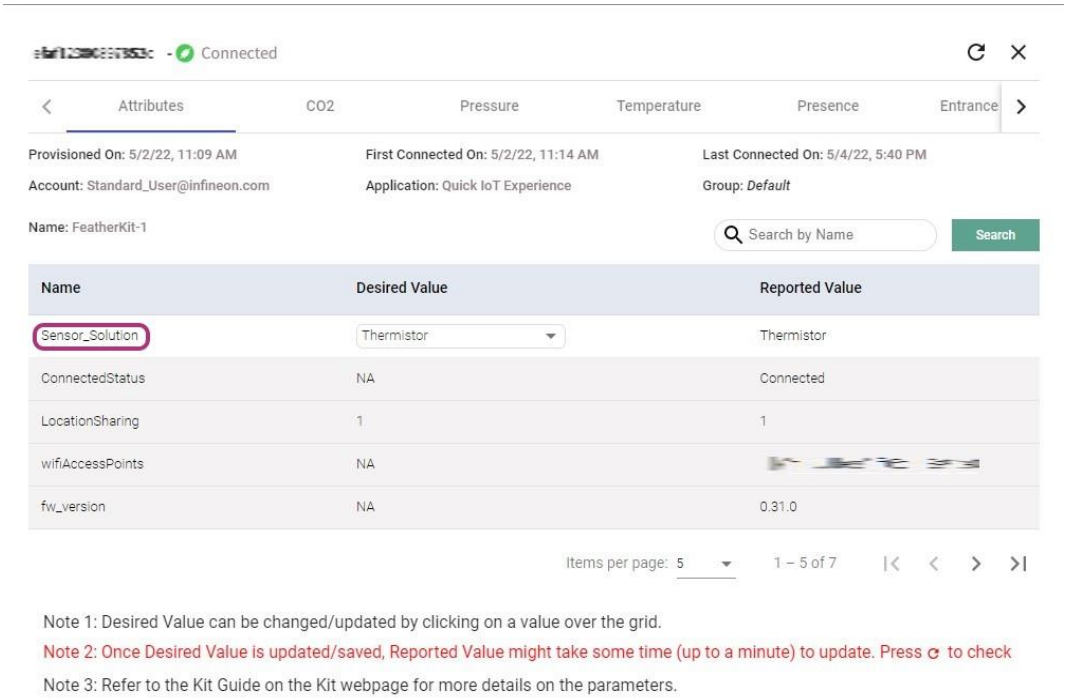


Figure 16 Attributes tab for connected device

Note: Selecting a new application can cause the connectivity to temporarily disconnect and reconnect from the Rapid IoT Connect Cloud Platform.

Table 3 Presence detection application attributes

Attribute	Description
max_range	0.66 – 5.0 Maximum detectable range for presence in meters. Default is 2.0.
sensitivity	High: • macro_threshold: 0.5, micro_threshold: 12.5 Medium: • macro_threshold: 1.0, micro_threshold: 25.0 Low: • macro_threshold: 2.0, micro_threshold: 50.0 Adjust the macro and micro threshold parameters to achieve different level of sensitivity. The higher the threshold, the lower the sensitivity. Default is High.

Attribute	Description
macro_threshold	0.1 – 100.0 Threshold value used in macro-movement detection. After changing this value, the sensitivity would be customized. The higher the threshold, the lower the sensitivity. Default is 0.5.
micro_threshold	0.2 – 99.0 Threshold value used in micro-movement detection. After changing this value, the sensitivity would be customized. The higher the threshold, the lower the sensitivity. Default is 12.5.
mode	macro_only/micro_only/micro_if_macro/micro_and_macro Detects the micro motion once the radar detects a major Macro movement. Default is micro_if_macro
kit_mask_level	Disable logs, enable minimal logs or full logs to cloud. 60: WARN, MINOR, MAJOR, FATAL all to UART terminal 62: INFO, WARN, MINOR, MAJOR, FATAL all to UART terminal 124: WARN, MINOR, MAJOR, FATAL all to Cloud UI as well as UART terminal

4.10 Change application attributes

- To view all attributes on one page, click on the **Items per page** dropdown menu at the bottom of the **Attributes** tab and adjust the number of items accordingly.
- For the Presence Detection use case, see the list of attributes as shown in Figure 17.

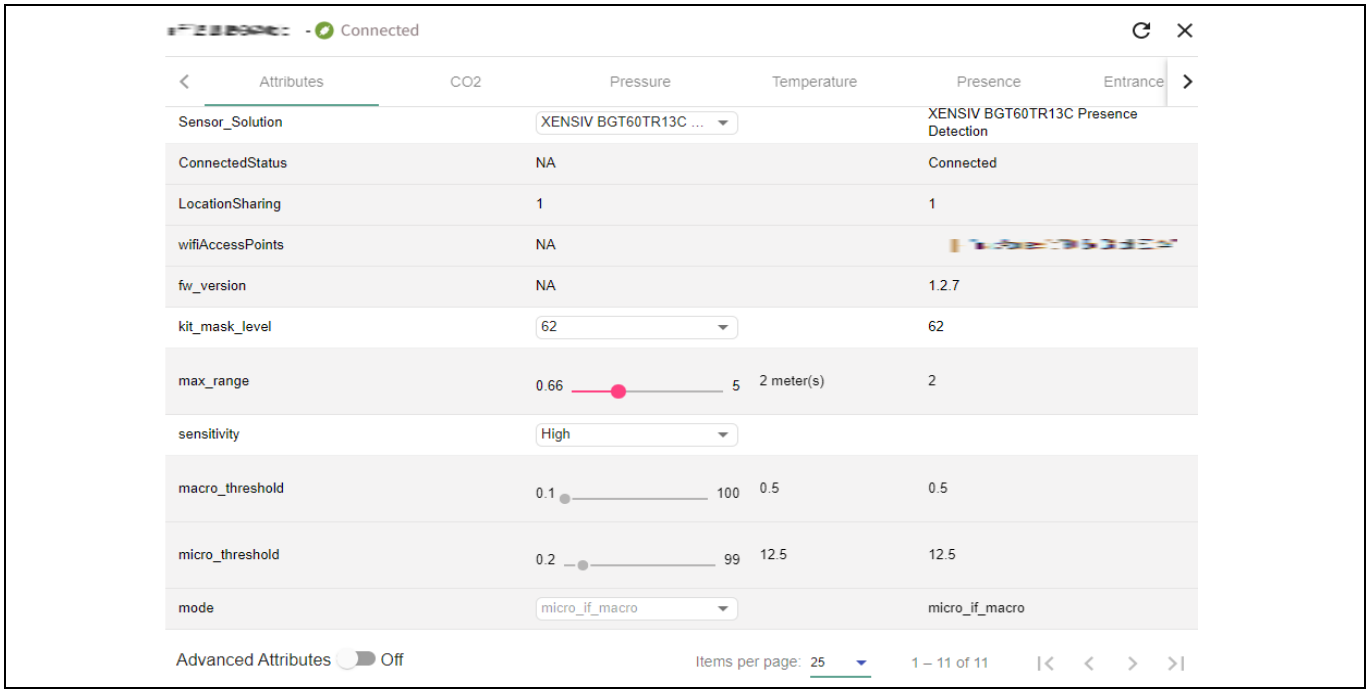


Figure 17 Presence detection attributes

- Set kit_mask_level values for device log levels.

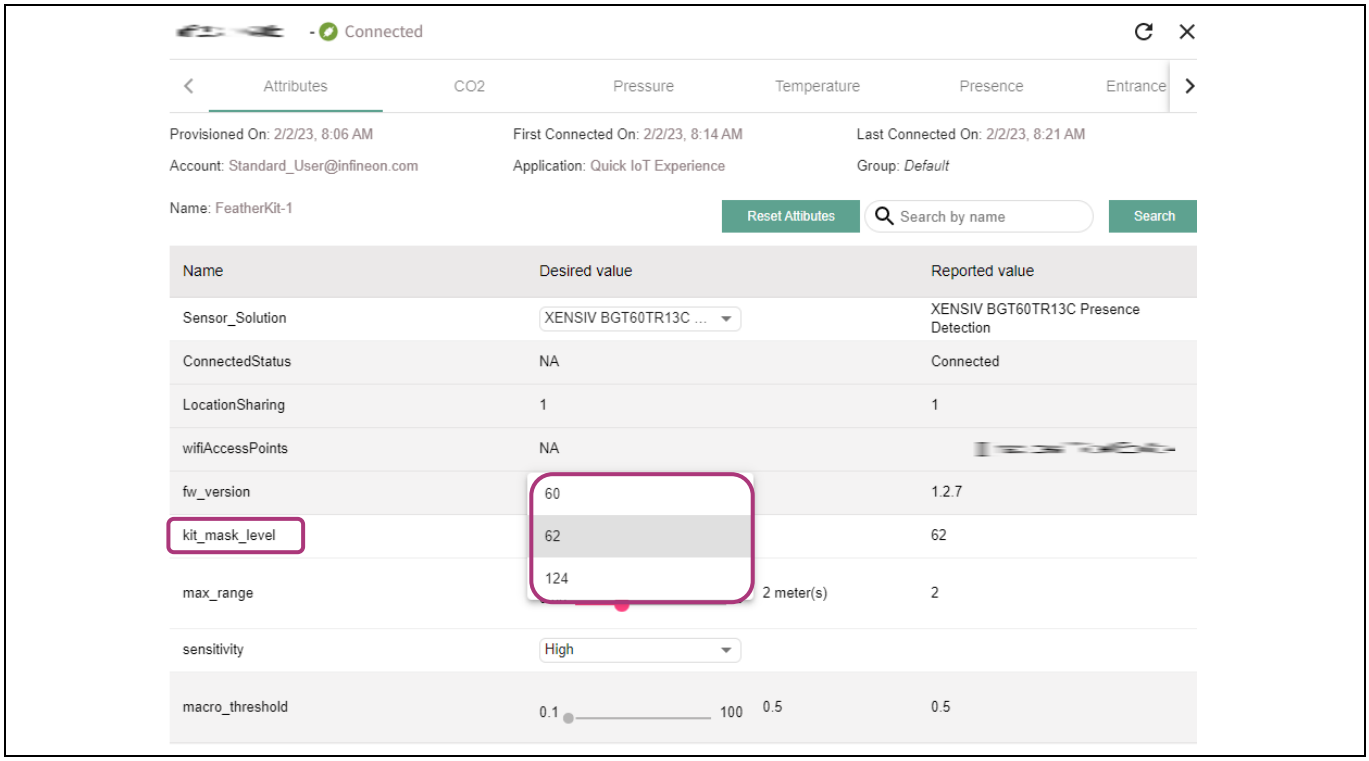


Figure 18 Device log level configuration

4.11 View sensor data

- To view your sensor data on the cloud, click on the desired tab at the top of the device details window. If you have the XENSIV™ BGT60TR13C wing board, select the **Presence** tab.
- By default, your application will be set to Thermistor. Click on the **Presence** tab to view the data represented as a graph for easy viewing. You can also download the raw data in .CSV format by clicking the **Download** button in the top-right corner.
- Note that the data retention period for a Standard User is 14 days, the data recorded more than 14 days ago cannot be retrieved. If you require a longer retention period, contact Infineon Support to upgrade your account.

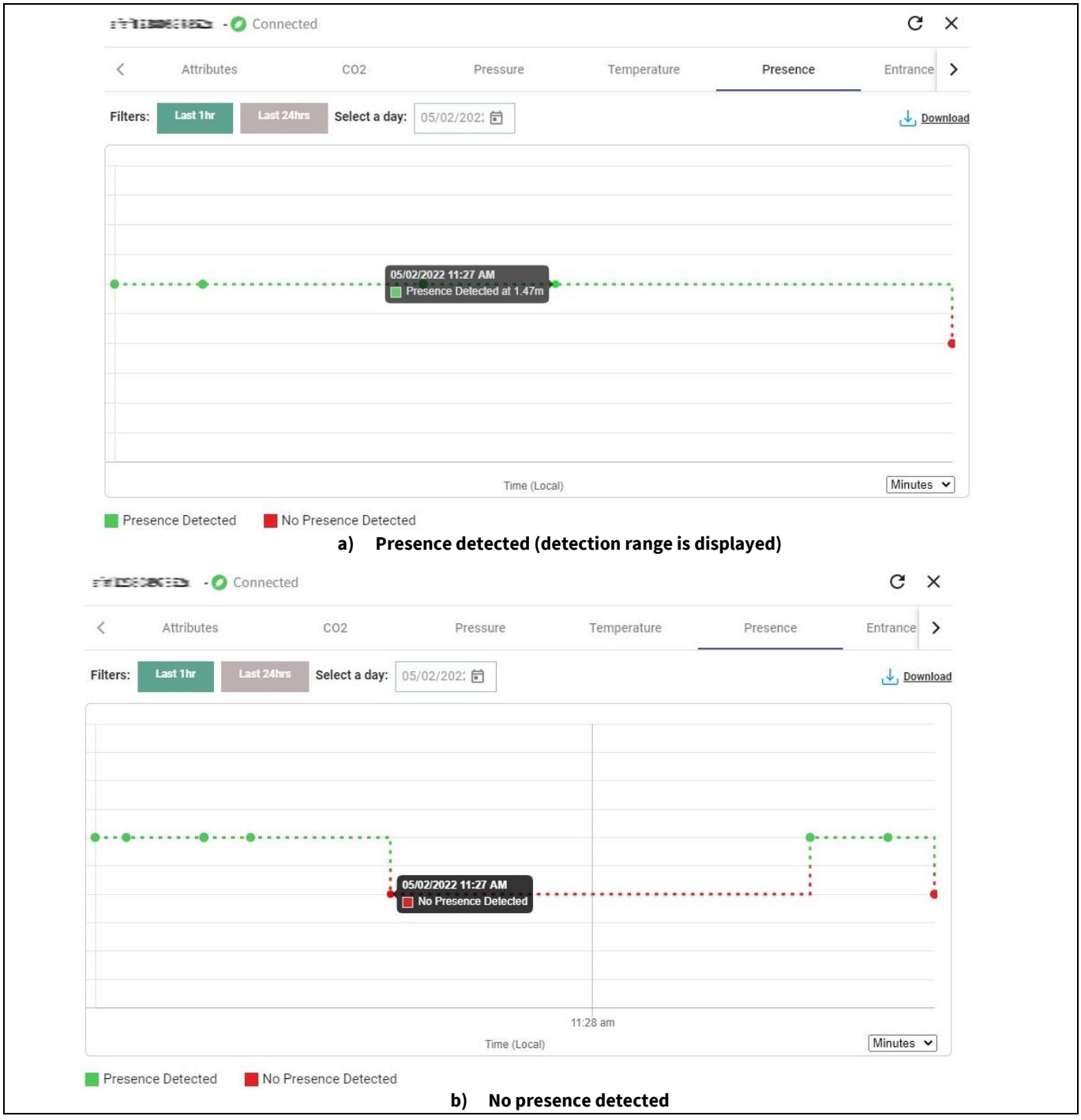


Figure 19 Presence detection data visualization

5 Build your own application

5.1 Overview

The XENSIV™ KIT BGT60TR13C is compatible with the xensiv-radar-presence library. ModusToolbox™ offers sample code examples that utilize this library.

The xensiv-radar-presence library provides APIs that enable the user to use existing radar applications such as presence detection or build applications on top. It detects both macro and micro movements in a configurable range using the data acquired by XENSIV™ FMCW radar sensor. It uses the sensor-dsp library that provides signal processing functions required to support the implementation of the presence detection algorithm. The library uses the ModusToolbox™ Hardware Abstraction Library (HAL) interface. See the README.md file for more details.

5.2 Code examples

5.2.1 PSoC™ 6 MCU: Human presence detection

This code example (mtb-example-psoc6-radar-presence) demonstrates Infineon's radar presence solution to detect human presence within a configurable distance. Powered by the XENSIV™ 60-GHz radar, this solution provides extremely high accuracy in detecting both micro and macro motions. The ability to detect micro motion offers unique benefits over conventional technologies deployed to detect human presence, therefore, making it perfect for user interaction with devices. The code examples demonstrate presence detection use cases implemented using the xensiv-radar-sensing library. See the README.md file for more details.

5.2.2 MQTT client: Human presence detection

This code example (mtb-example-wi-fi-mqtt-radar-presence) demonstrates implementing an MQTT client using the MQTT client library for XENSIV™ sensor with Infineon connectivity devices. This code example demonstrates implementing an MQTT client using the MQTT client library together with Infineon's radar presence solution to detect human presence within a configurable distance. Powered by the XENSIV™ 60-GHz radar, this solution provides extremely high accuracy in detecting both micro and macro motions. The ability to detect micro motion offers unique benefits over conventional technologies deployed to detect human presence, therefore, making it perfect for user interaction with devices. The library uses the following:

- AWS IoT device SDK MQTT client library that includes an MQTT 3.1.1 client
- xensiv-radar-sensing library allows the user to use existing radar applications such as presence detection, or build applications on top

If you need to use or customize the PDS source code, you can see the related code examples based on the xensiv-radar-sensing library available on Infineon's GitHub and supported through ModusToolbox™, see PSoC™ 6 MCU: Human Presence Detection with XENSIV™ 60-GHz Radar or MQTT client: Human presence detection.

References

[1] Infineon Technologies AG: *XENSIV™ KIT CSK BGT60TR13C user guide*; Available online

[2] Infineon Technologies AG: *AN228571 – Getting started with PSoC™ 6 MCU on ModusToolbox™ software*; Available online

[3] Infineon Technologies AG: *Using ModusToolbox™ software*; Available online

Revision history

Document revision	Date	Description of changes
1.00	2024-06-12	Initial release

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2024-06-12

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

AN124642

Important notice

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

Warnings

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.